Study on plant fiber/plastic composites as the substrate of floorboard

YANG Wen-bin[1,2], LI Jian[2], LIU Yi-xing[2]

[1] *Fujian Agriculture and Forestry University, Fuzhou 350001, P. R. China*

[2] *Key Laboratory of Bio-based Material Science and Technology (Northeast Forestry University), Ministry of Education, Harbin 150040, China"*

Abstract: Three kinds of composites (fiber/Polypropylene, fiber/Polyethelene, and fiber/Polystyrene) were made by using hot pressing process for substrate of floorboard and the properties of each kind of composites were tested. MORs of PP/wood fiber, PS/fiber, and PE/fiber composites with coupling agent added were raised by 18.4%, 37.1%, and 42%, respectively, compared to those without coupling agent. Among the three kinds of fiber/plastic composites, fiber/PP composite has best mechanical properties, and it can meet quality standard of eligible grade product and come up to the excellent grade products of China when the coupling agent is added. The performance of composite made of PE/fiber or PS/fiber can exceed qualified product grade only with coupling agent added

Keywords: Plant fiber; Plastic; Composites; Floorboard

CLC number: TS653 **Document code:** A **Article ID:** 1007-662X(2005)03-0245-02

Introduction

In recent years, as the enhancement of environmental consciousness and governments of various countries in the global range strengthening the protective measures to the natural environment, the development of design in material has moved towards harmonizing the relationship between material and environment. Natural macromolecular polymer and plant fiber have already aroused the attention from people as the potential advantage of the enhanced material. From the view point of utilization of raw material and its final process, the fiber from annual growing plant will have no harmful influence on the environment whether it is used as enhancement material of thermal plastic or heat-set plastic (Narayan 1992). Plant fiber enhancement materials has advantages of higher specific strength, low cost, low density (lower than all inorganic fibers), high toughness, good calorific performance, high ratio of length to radius, big specific surface area, biodegradation under the specific process conditioning and so on, compared with the traditional plastic packing material such as the talc powder and glass fiber,. Composite products compounded by fiber and thermal plastics have such advantages which is incomparable by any other materials as light density, cheap, fine processing performance, little wearing and tearing on equipment, renewable and getting degradation. Therefore plant fiber has wide application prospects in many fields. The scholars of many disciplines devoted to research of technology, properties and interface of wood plastic all the way and have made certain progress (Chuai *et al.* 2001, 2000; Simonsen 1997: Yan & Wang 2001; Lin *et al.* 2002). Yang Wenbin *et al.*(the author of this paper) has used wood particle and plastics to compound wood plastic composite (WPC) and analyzed the effect of the technical parameters on physical and mechanical properties (Yang *et al.* 2002a, 2002b).

For producing WPC with high fiber content, problems such as difficulty of shaping and bad fluidity are often met when traditional plastic processing method is used. Mould pressing shaping has the following advantages: producing the various plastic products in a flexible way, for instance, a slice of material, panel, capillary foamed plastics, basin, etc.; suited to packing the products with high calcium content and the products enhanced by wood fiber; little investment in the equipments; mould pressing larger plane products and using trough mould to produce in large scale. This paper probes into the performance characteristic of WPC under the shaping craft of mould pressing.

Material and Method

Material

Wood fiber used in producing hardboard is obtained from Sanming City of Fujian Province. The moisture content of fiber is 4%–6%, and the dimension of fiber is listed in Table 1. Plastic and coupling agents were bought from market.

Table1. The dimension of fiber

	Length /μm	Width /μm	Internal radius /μm	Ratio of length to width
Average	2049.84	36.60	29.42	56.8
Coefficient of variation	21%	13%	14%	20%

Instrument and equipment

Fifty ton pre-presser, 100-t hot presser, and S(X)M0.5 internal mixer that are made in Changzhou City of Jiangsu Province WDT-5 electronic all-purpose testing machine, and DMA242 dynamic mechanical analysis instrument were used in the study.

Mat preparation

According to test designed proportion (fiber and plastic quality take half each), the wood fiber, plastics and coupling agent, which is correspondingly maleic anhydride grafted compound for all plastics respectively, were mixed in internal mixer to cre-

Foundation item: The project was supported by: 1. the Natural Science Foundation of Fujian Province of China(E0310025), 2. Fujian province Educational Committee key project(JA03047), 3 Fujian province Science and Technology Committee key project(2003H015), 4. Foundation of key laboratory of biomaterial of Ministry of Education(04-08).

Biography: YANG Wen-bin (1966-), male, associate professor in the Fujian Agriculture and Forestry University, 350001, E-mail fafuywb@yahoo.com

Received date: 2004-10-12; **Accepted date:** 2005-01-10

Responsible editor: Chai Ruihai

ate a homogeneous mixture. The temperature of mixer was set at point which is 10℃ to 20℃ higher than the melting point of each plastic in order to achieve good hot conductivity and melt plastic easily As plastic or mixture of plastic and corresponding coupling agent melting, the wood fiber was put in to mix together for certain time, and then was taken out. The mixture can be pressed when the compound is still hot or be hot pressed after mixture from mixer is crashed and cool. Obviously the former processing method can press board easier and save more energy than the second one, because the process in which plastic was heated again was unnecessary. However, the latter processing method was only adopted in this test due to the limited condition.

The granule from mixer was then put into a closed die and then sent into hot presser together with die to form the board by hot press. After that, the fast cooling method was used to cool the press board nearly 70℃, taking out the WPC board, sawing the test sample for the mechanical and processing properties test.

Results and discussion

The experimental results show that strength of WPC is significant different for the composites with coupling agent and without coupling agent. For all the three kinds of plastics (PP, PS, PE) and wood, the strength of composite with coupling agent is stronger than that without coupling agent (Table 2). MORs of PP/wood fiber, PS/fiber, and PE/fiber composites with coupling agent were raised by 18.4%, 37.1%, and 42%, respectively, compared to those without coupling agent. According to the Chinese standard of floor board, the strength of PP/fiber composite with Polypropylene Grafted Maleic Anhydride reached the excellent grade standard (The National Standard of P.R. China 2000)(≥40Mpa), strengths of PS/fiber composite and PE/fiber composite with MAPE come up to qualified grade(≥30MPa). Similar results were also found in other properties of composite such as MOE, impact strength. Thickness swelling of the composite with coupling agent was significantly lower than that of the composite without coupling agent. The thickness swelling of PP/fiber, PS/fiber, and PE/Fiber composites with MAPP decreased by 36.4%, 38.4%, and 39%, respectively. The dimensional stability of plastic/fiber composites is very good no matter whether coupling agent is added. The thickness swelling of composite is greatly smaller than that of hardboard, MDF and particleboard.

Table 2. Mechanical properties of WPC

sample	Modulus of Rupture (MPa)	Modulus of Elasticity (MPa)	Impact trength (KJ/m^2)	Internal bond strength(MPa)	Thickness Swelling(%)	Holding nail force /N	
						Face	side
PP+fiber	33.95	2231.2	9.152	>1.6	1.1	1300	1190
PP+PP grafted by Maleic Anhydride +fiber	40.21	3118.3	13.23	>1.6	0.7	1540	1630
PS+fiber	23.64	2789.6	8.16	>1.6	1.01	-	-
PS+ PS grafted by Maleic Anhydride +fiber	32.42	3511.3	13.02	>1.6	0.62	-	-
PE+fiber	25.47	1647.8	15.74	>1.6	1.23	-	-
PE+ PE grafted by Maleic Anhydride +fiber	36.17	2333.5	20.74	>1.6	0.75	-	-

In the internal bonding test, broken area of samples all were in an interface between the sample and holding device, and the strength of internal bonding for all samples was more than 1.6 MPa, which is significantly greater than that of Chinese standards for floor board and wood based panel. Consulted the standard of MDF (in which holding nail force>1000N in surface and >800N in side), the holding nail force of composite also meet the standard demand. Adding coupling agent can help the increase of holding nail force in the case of same ratio of fiber to plastic.

The reason for enhanced strength is that plastics grafted by Maleic Anhydride can improve the compatibility of interface by esterification reaction between plastic and wood (Chuai *et al.* 2000), and in the Dynamic Mechanical Analysis, it also showed that plastics grafted by Maleic Anhydride can increase Store Modulus of Elasticity by improving the glass transition point of composites (Yang 2002).

Conclusions

The result of the experiment of WPC as mother board of floorboard indicates that PP/fiber composites has good performance, satisfy the demand of qualified product, and can reach excellent grade with coupling agent added. The performance of composite made of PE/fiber or PS/fiber can exceed qualified product grade only with coupling agent added.

References

Chuai Chengzhi, Li Shu and Lin Yanqqin. 2000. Study on compatibility and the properties of Polypropylene/grafted wood fiber composites [J]. China Plastic, **14**(5): 23–28. (in Chinese)

Chuai, C.Z., Almdal, K, Poulsen, L., Placket, D. 2001. Conifer fibers as reinforcing materials for polypropylene based composites [J]. Journal of Applied Polymer Science, **80**: 2833–2841.

Lu, J. Z., Q. Wu, and H.S. Mcnabb, Jr. 2000. Chemical coupling in wood fiber and polymer composites: a review of coupling agents and treatments. Wood and Fiber Science [J], **32**(1): 88–104.

Lin Qunfang, Zhou Xiaodong, Dai Gance, *et al.* 2002. Methods to modify mechanical properties of polypropylene composites reinforced by wood flour. Modern Chemical Industry [J], **22**(5): 37–41.

Narayan, R. 1992. Biomass (Renewable) resources for production of materials, chemicals, and fuels-A paradigm [C]. In: ACS(American Chemicals Society) symposium series, 476.

Simonsen, J., Hong, Z.Q, Rials, T.G. 1997. The properties of the wood-polystyrene interphase determined by inverse gas chromatography [J]. Wood and Fiber Science, **29**(1): 75–84.

The National Standard of P.R. China. 2000. Wood based floorboard laminated by impregnated pape. GB/T18102–2000.

Yan Haopen, Wang Jianjun. 2001. Study on the Composite or wood—synthetic Fiber [J]. China Wood Industry, **15**(4): 9–11. (in Chinese)

Yang Wenbin, 2002. The discarded plastic-wood particle composites and its composite mechanism [D]. Research report of post doctor of Northeast Forestry University, Harerbin. (in Chinese)

Yang Wenbin, Liu Yixing, Li Jian, *et al.* 2002a. The effect of main technical parameters on wood plastic composite properties [J]. Journal of Northeast Forestry University, **30**(4): 11–13. (in Chinese)

Yang Wenbin, Liu Yixing, Li Jian, *et al.* 2002b. Physics and mechanical properties of composites made with wood particle and recycled EPS plastic [J]. Journal of Fujian Forestry College, **22**(4): 299–303. (in Chinese)